

Studies on ψ' and Υ measurements at $|y| < 0.35$ in Au+Au collisions

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Abstract

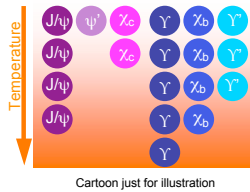


Quarkonia are probes of the hot and dense matter that is formed in the most central relativistic heavy ion collisions. Lattice QCD scenarios predict a suppression of the different quarkonium states as a function of their binding energy and the system temperature or energy density. With the increase of the medium temperature, the ground states disappear last. Though the uncertainties on the cold nuclear effects are large, current PHENIX J/ψ data suggest that regeneration of uncorrelated heavy quark pairs may also be at play. The measurement of the relative yields of the different quarkonium states should provide important information on quarkonia production, melting and/or regeneration mechanisms. We report on the PHENIX Collaboration progress towards measuring ψ' and Υ at $|y| < 0.35$ in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV.

The motivation

Lattice QCD calculations predict a sequential melting of the different quarkonium states as a function of their binding energy and the system temperature and/or energy density [1]. SPS experiments charmonium results are in agreement with those predictions.

However, recent PHENIX measurements suggest that regeneration of uncorrelated heavy quarks into quarkonium states may also be at play. Recombination probability depends quadratically on the number of heavy quarks and varies with the state binding energy [2,3]. The relative measurement of the different quarkonium states at RHIC is then of crucial interest to learn on (and possibly discriminate between) those scenarios.



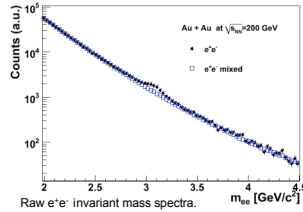
Example of IQCD dissociation temperature prediction [1].

	$J/\psi(1S)$	$\chi_c(1P)$	$\psi'(2S)$	$\Upsilon(1S)$	$\chi_b(1P)$	$\Upsilon'(2S)$	$\chi_b'(2P)$	$\Upsilon''(3S)$
M [GeV]	3.10	3.41	3.69	9.46	9.86	10.02	10.23	10.36
E_b [GeV]	0.64	0.20	0.05	1.10	0.67	0.54	0.31	0.20
T_d/T_c	2.1	1.16	1.12	> 4.0	1.76	1.60	1.19	1.17

Is ψ' measurement possible?

The experimental challenge:

Au+Au collisions are a high multiplicity environment characterized by a huge combinatorial background. Mixed event background subtraction allows to correctly describe the combinatorial background while minimizing the uncertainties.



The observation:

There is no clear evidence for ψ' production in minimum bias Au+Au collisions. Therefore we work to compute a ψ'/ψ upper-limit.

ψ'/ψ upper-limit calculation:

- The method:
 - ✓ Di-electron continuum and J/ψ spectra shapes are well reproduced by a fit.
 - ✓ Simulations allow to understand the experimental peak resolution evolution with the resonance mass. Therefore we fix the ψ' width by extrapolating the measured J/ψ width.
 - ✓ The procedure used to compute the ψ'/ψ upper-limit consists on an iterative fit of the spectra varying the possible number of ψ' . The dependence of the fit χ^2 ($\Delta\chi^2$) with the number of imposed ψ' defines the upper-limit.

- The systematics:
 - The calculation depends on the fit parameters, therefore we allow variations on:
 - ✓ Resonances shape description
 - ✓ Continuum functional forms
 - ✓ ψ' peak width
 - ✓ Prefit and fit mass ranges

- Work in progress, keep tuned !

References:

[1] Satz, J.Phys.G32:R25 (2006); arXiv: hep-ph/0512217
[3] O. Linnyk et al. Nucl. Phys. A807:79-104, 2008

[2] PHENIX Coll. Phys.Rev.Lett. 98, 232301 (2007); arXiv: nucle-ex/0611020
[4] CDF Coll. Phys.Rev.Lett. 84 (2000) 2094; arXiv:hep-ex/9910025

[5] E772 Coll. Phys.Rev.Lett. 64, (1990) 2479.

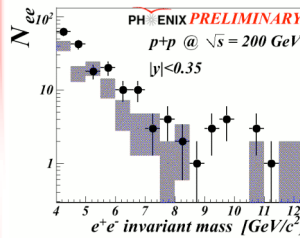
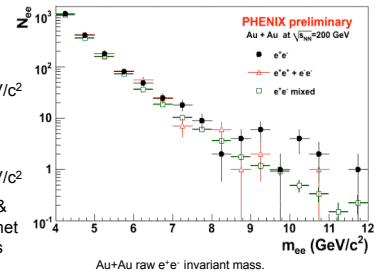
High mass (Υ) measurements

The observation:

In Au+Au collisions we measure:

- ✓ 4166 ± 422 (stat) $^{+187}_{-304}$ (syst) J/ψ
 - ✓ $17 e^+e^-$ in m_{ee} [8.5,11.5] GeV/ c^2
 - ✓ $5 e^+e^- + e^+e^-$ in m_{ee} [8.5,11.5] GeV/ c^2
- In p+p collisions we measure:
- ✓ 2653 ± 70 (stat) ± 345 (syst) J/ψ
 - ✓ $12 e^+e^-$ in m_{ee} [8.5,11.5] GeV/ c^2
 - ✓ $1 e^+e^- + e^+e^-$ in m_{ee} [8.5,11.5] GeV/ c^2

There is a net signal in both Au+Au & p+p samples. In addition, there is a net suppression of the Au+Au high mass signal over J/ψ ratio.



The analysis:

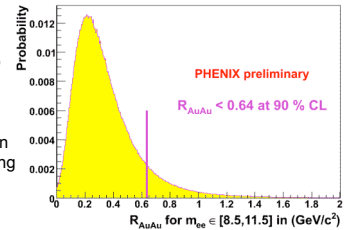
As the Υ physical background subtraction in Au+Au collisions is challenging, here we only compute the high mass R_{AuAu} upper-limit, without consideration of its origin. To reduce the uncertainties, the number of J/ψ in each sample serves as relative normalization.

The high mass range we look at is chosen in such a way as to include Υ , Υ' & Υ'' by extrapolating the J/ψ measured resolution to higher masses (simulation driven extrapolation, as for ψ' studies).

$$R_{AA}[8.5,11.5] = \frac{(N[8.5,11.5] / N[J/\psi])_{AA}}{(N[8.5,11.5] / N[J/\psi])_{pp}} \times \frac{(A \times \epsilon[J/\psi] / A \times \epsilon[\Upsilon])_{AA}}{(A \times \epsilon[J/\psi] / A \times \epsilon[\Upsilon])_{pp}} \times R_{AA}[J/\psi]$$

The high mass R_{AuAu} calculation:

The high mass counts R_{AuAu} probability distribution is computed. A detailed Poissonian statistics study is performed to properly account for the measured low statistics in both the unlike and like sign pairs samples. The influence of the uncertainties of the other terms involved on the R_{AuAu} calculation is considered including their Gaussian probability distributions.



To do: Subtract the physical continuum.

Playing with numbers...

The high mass R_{AuAu} is suppressed, but why ?

- Possible influences:
 - ✓ Tevatron measurements indicate that $\sim 50\%$ of Υ are from χ_b [4]. But this is for $p_T > 8$ GeV/c, it might decrease for smaller p_T .
 - ✓ Cold nuclear matter effects (anti-shadowing, absorption). E772 Υ nuclear dependence corresponds to $R_{dA}(\Upsilon + \Upsilon' + \Upsilon'') \sim 0.81$ [5]. But we do not know how it evolves with the colliding system and energy.
 - ✓ IQCD predicts Υ' & Υ'' suppression at RHIC [1].
 - ✓ Drell-Yan and $b\bar{b}$ decays contribution.
- Guess estimate of the high mass R_{AuAu} independent of our measurement:

Continuum	Cold Nuclear Matter	Hot Nuclear Matter	Hypothetic high-mass R_{AuAu}
1.0	0.81	0.73	0.60 ?
$1 + 0.10 = 1.10$ (*)	0.81	0.73	0.65 ?
$1 + 0.10 = 1.10$ (*)	0.81	0.73×0.50 (from χ_b) (**)	0.33 ?

* Let's guess that continuum fraction is $\sim 10\%$ (p+p studies) and that it is not suppressed.
** Imagine that the χ_b feed-down contribution does not vary with p_T .